

# Energy

Since the mid-19th century, the American economy has shifted dramatically from an agrarian, rural society towards a largely urban and industrial base powered by fossil fuels—coal, oil, and gas. Electricity, which was unavailable until the 1880s, is now ubiquitous. Within a span of just 100 years, the United States became the world's largest producer and consumer of fossil fuels and roughly tripled its per capita consumption of energy.

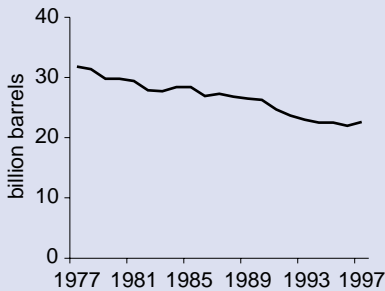
The dominance of fossil fuels in the American economy continues today, but not without growing concerns about their environmental implications—particularly their likely role in modifying global climate. Combustion of fossil fuels emits carbon dioxide, the main “greenhouse gas” that scientists think may be contributing to a warming of the planet. The climate issue has increased support for expansion of renewable energy sources such as solar and wind energy, but development of these sources has been slowed by the continuing low cost of fossil fuels. Other methods of generating electricity also pose significant environmental problems. For example, the use of large dams to generate hydroelectric power has had a devastating impact on

salmon and other fish, and the flooding of large areas has destroyed important ecosystems. Nuclear power plants, while avoiding the problem of greenhouse gas emissions, nonetheless pose a significant environmental challenge regarding the long-term disposal of nuclear waste.

Energy also is a major source of conventional pollution. The combined effects of the production, distribution, and consumption of fossil fuel energy represent the nation's largest source of pollution. These impacts can be reduced through regulatory-based mechanisms, improved energy efficiency, the introduction of more efficient technologies, and further expansion of market-based incentives to make energy as cost-effective, reliable, and environmentally benign as possible.

Energy production has traditionally been vertically integrated. In the 1990s, however, the U.S. electric power industry is beginning a complex transition to a competitive market. California, New York, and most of the New England states are opening their retail electric power markets to competition. Regulators are experimenting with alternative forms of regulation, including performance-based rates. With

**Figure 9.1 U.S. Crude Oil Reserves, 1977-1997**



Source: See Part III, Table 9.1.

Note: Data refer to proved reserves.

competition on the horizon, investor-owned utilities are reducing staff and reorganizing their companies to lower costs. These issues are explored in detail in a DOE study on the electric power industry ([http://www.eia.doe.gov/cneaf/electricity/chg\\_str/](http://www.eia.doe.gov/cneaf/electricity/chg_str/)).

## CURRENT TRENDS

### Hydrocarbon Reserves

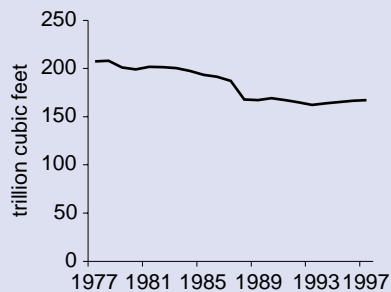
The United States had large hydrocarbon reserves and was essentially self-sufficient in petroleum until the 1950s and in natural gas until the late 1980s, when consumption began to outpace production. Over the 1977-97 period, proved reserves of crude oil and natural gas in the United States fell substantially and imports rose to make up the difference. Crude oil reserves, estimated at 31.8 billion barrels in 1977, were down to 22.6 billion barrels by 1997 (Figure 9.1). Natural gas reserves, which were estimated at 207.4 trillion cubic feet in 1977, fell to 167.2 trillion

cubic feet in 1997 (Figure 9.2). (Part III, Table 9.1)

### U.S. Energy Production by Source

Fossil fuels have dominated U.S. energy production since the early part of this century, but the relative shares have changed (Figure 9.3). Coal relinquished its place as the premier fuel in the years before World War II. However, since the 1950s, coal production has more than doubled, in part because of nationwide use by electric utilities. Petroleum got a major boost with the advent of mass-produced automobiles in the early part of this century. Oil production from domestic reserves rose to the 20-22 quadrillion btu range during the 1970s and 1980s, but declined to about 16 quads in the mid-1990s. Natural gas was used extensively as a lighting fuel until the rapid development of electricity at the turn of the century. The development of steel pipelines, which allowed large volumes of gas to be easily and safely transported over many miles,

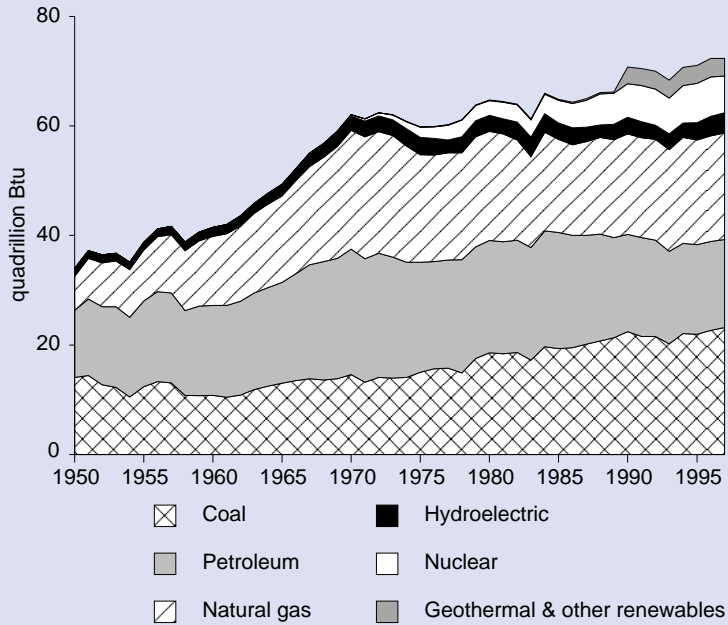
**Figure 9.2 U.S. Natural Gas Reserves, 1977-1997**



Source: See Part III, Table 9.1.

Note: Data refer to proved reserves.

Figure 9.3 U.S. Energy Production by Source, 1950-1997



Source: See Part III, Table 9.2.

Note: Coverage of nonutility use of renewable energy was expanded in 1990.

launched the modern natural gas industry. Domestic production peaked in the 1970s, then fell steeply through the mid-1980s before stabilizing in a range of 17-19 quads in the 1980s and 1990s. Nuclear energy production has grown from negligible production in 1960 to 6.69 quads in 1997.

Some renewable energy technologies, such as water- and wind-driven mills, have been in use for centuries. Hydro-power production has more than doubled, from 1.42 quads in 1950 to 3.68 quads in 1997, to now represent 5 percent of total U.S. energy production. Most of the rest of U.S. renewable energy production comes from biofuels and geothermal,

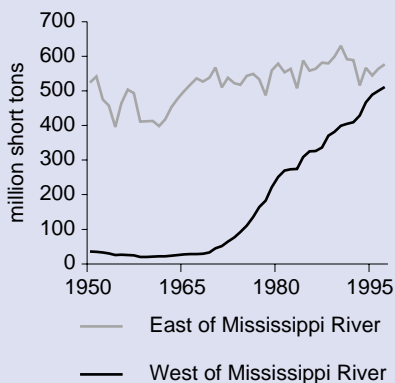
followed by wind and solar. (Part III, Table 9.2)

### U.S. Coal Production

U.S. coal production has undergone substantial changes in this century in both mining methods and mine location.

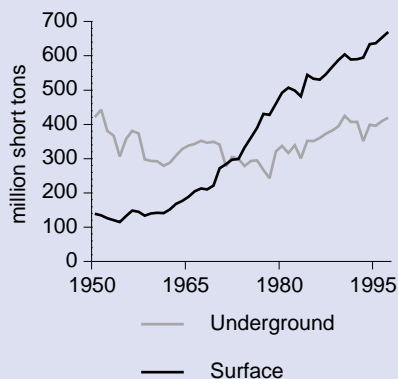
Over the past several decades, coal production shifted from primarily underground mines to surface mines. In addition, the coal reserves of Wyoming and other areas west of the Mississippi River underwent tremendous development (Figure 9.4). Since 1960, coal production in the West has grown dramatically, from 21 million tons in 1960 to 511 million

**Figure 9.4 U.S. Coal Production by Location, 1950-1997**



Source: See Part III, Table 9.3.

**Figure 9.5 U.S. Coal Production by Mining Method, 1950-1997**



Source: See Part III, Table 9.3.

tons in 1997, or nearly as much as the 577 million tons produced in the East.

Technological improvements in mining and the shift toward more surface-mined coal have led to great improvements in coal mining productivity. In 1997, U.S. production of coal reached a record-high level of 1.09 billion short tons

and was second worldwide after China. Surface mining produced slightly more than one-half of this record quantity (Figure 9.5). (Part III, Table 9.3)

### ***Petroleum Production and Imports***

Until the 1950s, the United States produced nearly all the petroleum it needed. But by the end of the decade the gap between production and consumption began to widen and imported petroleum became a major component of the U.S. petroleum supply. After 1992, net imports exceeded production (Figure 9.6). Today the United States produces about 6 million barrels per day while importing nearly 10 million barrels per day. (Part III, Table 9.4)

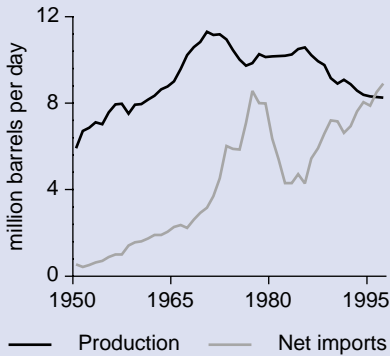
### ***Natural Gas Production***

The first all-welded pipeline over 200 miles in length was built in 1925, from Louisiana to Texas. U.S. demand grew rapidly thereafter, especially following World War II. Residential demand grew fifty-fold between 1906 and 1970. U.S. natural gas production peaked at about 22 trillion cubic feet in 1973, and has since drifted downwards in the range of 16-20 trillion cubic feet annually. In 1997, gas production totaled 18.96 trillion cubic feet. (Part III, Table 9.5)

### ***Electricity Net Generation***

Electric power arrived barely a hundred years ago, but it radically transformed and expanded energy use. Electricity's broad and increasing usage from 1950 to

**Figure 9.6 U.S. Petroleum Production and Net Imports, 1950-1997**



Source: See Part III, Table 9.4.

Note: Petroleum = crude oil & natural gas plant liquids.

1997 is evident in many consumption indicators. For example, while the U.S. population grew by 43 percent, total electricity generation grew by more than 920 percent (Figure 9.7). In 1997, the residential sector used the most electricity (1.072 trillion kilowatt-hours), followed closely by the industrial sector (1.036 trillion kilowatt-hours), and then the commercial sector (0.913 trillion kilowatt-hours).

Coal has been and continues to be the source of most electricity, producing over half (1.788 trillion kilowatt-hours) of all electricity generated in 1997 (Figure 9.8). Hydroelectric power was an early source of U.S. electricity (accounting for almost a third of all electricity in 1950) and remains a dependable contributor (about 10 percent of the total in 1997). Natural gas and petroleum grew steadily as sources of electricity in the late 1960s, but have since declined. Nuclear electricity began production in 1957 and increased steadily

(except for a downturn following the accident at Three Mile Island) until 1997 when nuclear generation declined seven percent. Nonetheless, nuclear power supplied about 20 percent of U.S. electricity generation in 1997. (See Part III, Table 9.6)

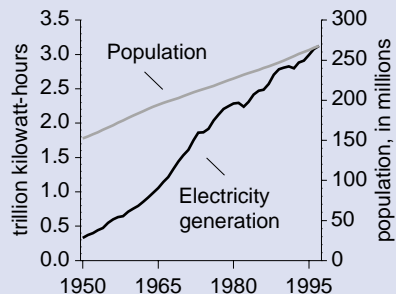
### **Nuclear Power Plant Operations**

The number of operating nuclear power plants rose to a high of 112 in 1990. Since then, the number of operating units has declined to 107. Net generation of electricity reached a high of 674 billion kilowatt-hours in 1996, but declined to 629 billion kilowatt-hours in 1997. (Part III, Table 9.7)

### **U.S. Net Energy Imports by Source**

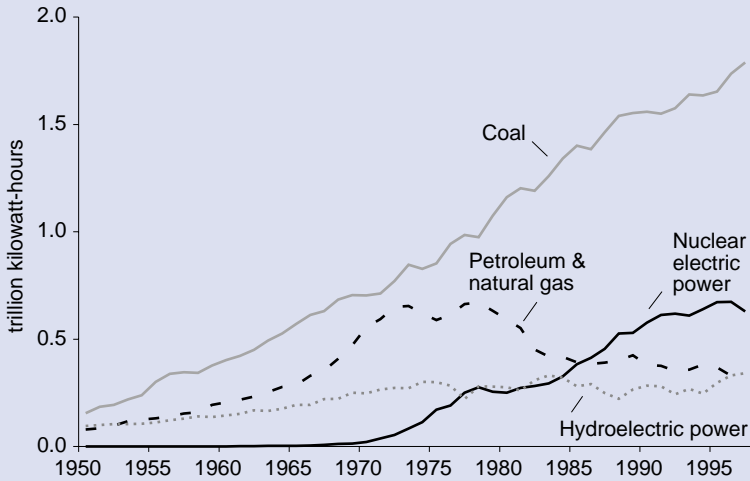
Petroleum is by far the largest source of imported energy in the U.S., accounting for 19.12 quadrillion Btus out of the net total of 20.39 quads of energy imports in 1997 (Figure 9.9). The 1997 energy

**Figure 9.7 Growth in U.S. Population and Electricity Generation, 1900-1997**



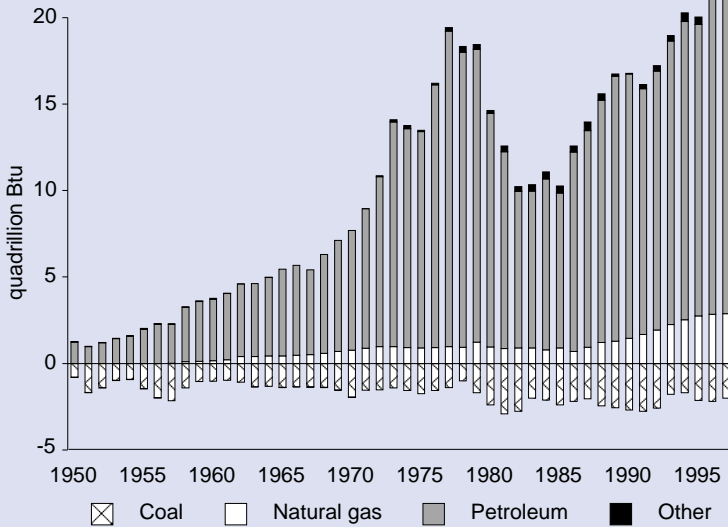
Source: See Part III, Table 1.1 and Table 9.6.

Figure 9.8 U.S. Electricity Generation by Source, 1950-1997

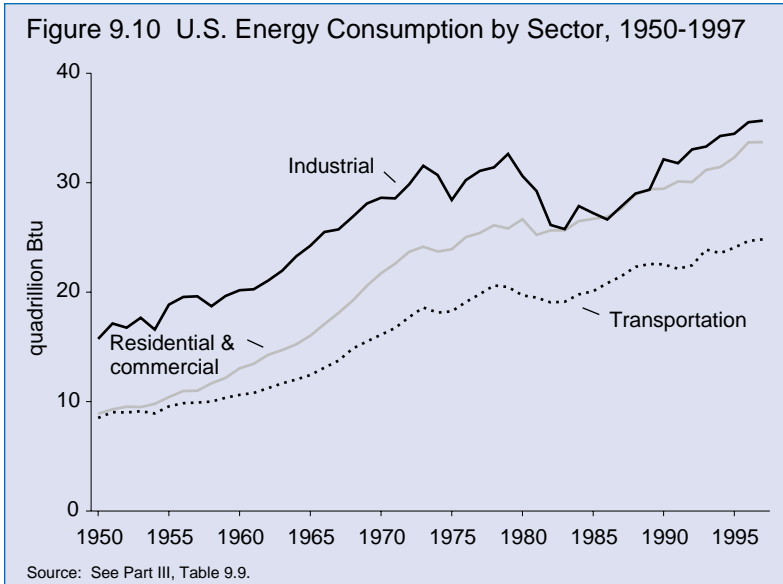


Source: See Part III, Table 9.6.

Figure 9.9 Net U.S. Imports of Energy Sources, 1950-1997



Source: See Part III, Table 9.8.



import level represents a 16-fold increase over the 1950 level. (Part III, Table 9.8)

### **U.S. Total Energy Consumption by Sector**

In 1950, U.S. industry accounted for almost half of total energy consumption—15.7 quads out of a national total of 33.1 quads, compared to 8.9 quads for combined residential and commercial and 8.5 quads for the transportation sector. Since then, all sectors have increased their consumption, but residential and commercial consumption has risen to be nearly equal to the industrial sector (Figure 9.10). (Part III, Table 9.9)

### **Per Capita Total Energy Consumption**

The efficiency with which the U.S. uses energy has improved over the years.

One such measure is the amount of energy consumed to produce a (constant) dollar's worth of gross domestic product (GDP). By that measure, efficiency improved by 36 percent between 1950 and 1997, as energy consumption per dollar of GDP fell from 20.5 thousand Btu to 13.1 thousand Btu (Figure 9.11). Nevertheless, a growing population and econo-

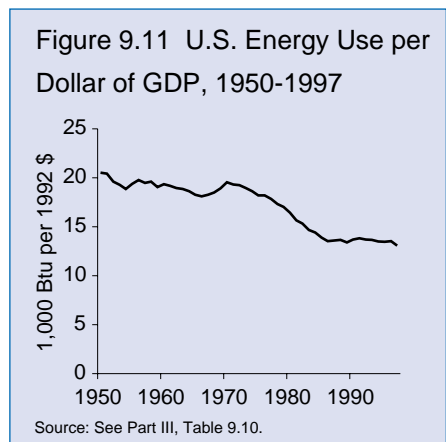
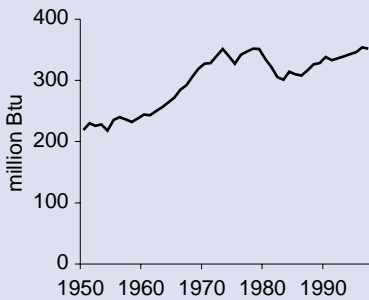
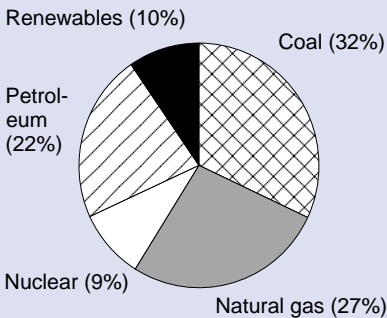


Figure 9.12 U.S. Energy Use per Capita, 1950-1997



Source: See Part III, Table 9.10.

Figure 9.13 Renewable Energy as Share of Total Energy, 1997



Source: See Part III, Table 9.2.

my drove total energy use up. As the U.S. population expanded from 151 million people in 1950 to 268 million people in 1997 (an increase of nearly 80 percent), total energy consumption grew from 33 quadrillion Btu to 94 quadrillion Btu (up nearly 200 percent) and per capita energy consumption rose from 219 million Btu to 352 million Btu over the period (an increase of 60 percent) (Figure 9.12). (Part III, Table 9.10)

## U.S. Renewable Energy Production

U.S. renewable energy production is now almost 10 percent of total U.S. energy production (Figure 9.13).

In 1960, conventional hydroelectric power provided essentially all of the renewable energy in the nation. By 1997, hydropower had more than doubled, growing from 1.6 quads in 1960 to 3.7 quads in 1997 (Figure 9.14). But total renewable energy production grew to 6.9 quads, thanks to rapid growth in biofuels production and modest growth in solar, wind, and geothermal energy. (Part III, Table 9.11)

Industrial sources and electric utilities account for about 90 percent of all renewable energy consumption. (Part III, Table 9.12)

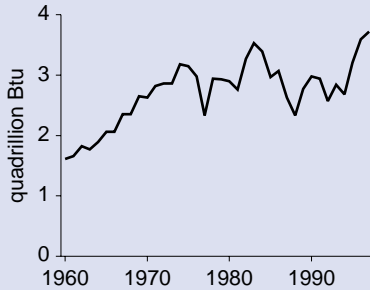
## U.S. Energy Intensity by Source

Energy intensity is another measure of energy efficiency. In the late 1970s and early 1980s, energy intensity in the residential and commercial sectors fell as a result of energy conservation improvements; since then, estimates of energy intensity in these two sectors have been about the same. Similarly, energy intensity fell during the 1977-84 period in the manufacturing sector, but has apparently stayed about the same since then.

Energy intensity for both passenger cars and trucks has declined steadily over the 1977-95 period, but the decline has been less dramatic in the 1990s. (Part III, Table 9.14)



**Figure 9.14 U.S. Conventional Hydroelectric Power Generation, 1960-1997**



Source: See Part III, Table 9.11.

Note: Excludes pumped storage facility production.

## ONLINE RESOURCES

The web site maintained by the Department of Energy's Energy Information Administration (<http://www.eia.doe.gov>) provides a wealth of data and information on energy.

Particularly noteworthy is DOE's *Annual Energy Review 1997* (<http://www.eia.doe.gov/emeu/aer/contents.html>). The review includes numerous tables on end-use energy consumption, financial indicators, energy resources, petroleum, natural gas, coal, electricity, nuclear energy, renewable energy, international energy resources, and environmental indicators.

DOE's Office of Energy Efficiency and Renewable Energy maintains the Energy Efficiency and Renewable Energy Network (EREN), which provides information on alternative fuels, geothermal energy, solar energy, wind energy, and on energy efficiency for industry, utilities, buildings, and transportation. Specialized resources also are available on the environment (<http://www.eren.doe.gov>).

The Oak Ridge National Laboratory (<http://www.ornl.gov>) is a multiprogram science and technology laboratory managed for DOE by Lockheed Martin Energy Research Corporation.

In addition to its research on energy, ORNL is one of the world's leading sources of information on greenhouse gas emissions. ORNL's Carbon Dioxide Information Analysis Center—linked to nearly 100 monitoring stations worldwide—is the most comprehensive CO<sub>2</sub> database on earth. The center tracks emissions, estimates the offsetting effects of plants and oceans, and uses sophisticated computer models to project future concentrations (<http://cdiac.esd.ornl.gov>).

CDIAC's latest estimates of global, regional, and national fossil fuel CO<sub>2</sub> emissions are available ([http://cdiac.esd.ornl.gov/trends/emis/tre\\_glob.htm](http://cdiac.esd.ornl.gov/trends/emis/tre_glob.htm)). The 1996 estimate for global CO<sub>2</sub> emissions, 6,518 million metric tons of carbon, is the highest emission estimate recorded to date.

Based in Paris, the International Energy Agency (IEA) provides a wealth of information about global energy production, consumption and trends. The IEA site (<http://www.iea.org/homechoi.htm>) includes research on world energy prospects to 2020, on the world energy outlook, and on IEA's world energy model.

IEA's Energy Technology Data Exchange and Energy Database (<http://www.etde.org>) provides access to more than 3.7 million scientific and technical citations. Updated twice monthly, the database contains bibliographic references and abstracts to journal articles,

reports, conference papers, books, and other documents. The database includes information on the environmental aspects of energy production. The data exchange

also provides a directory for full-text government reports and conference literature and identifies subject-area experts.

## SELECTED RESOURCES

### Coal

U.S. Department of Energy, Energy Information Administration, *Coal Industry Annual—1997* (DOE, EIA, Washington, DC, 1998). ([http://www.eia.doe.gov/cneaf/coal/cia/summary/cia\\_sum.html](http://www.eia.doe.gov/cneaf/coal/cia/summary/cia_sum.html))

—, *Carbon Dioxide Emission Factors for Coal* (DOE, EIA, Washington, DC, 1994). ([http://www.eia.doe.gov/cneaf/coal/quarterly/co2\\_article/co2.html](http://www.eia.doe.gov/cneaf/coal/quarterly/co2_article/co2.html))

### Electricity

U.S. Department of Energy, Energy Information Administration, *The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update* (DOE, EIA, Washington, DC, 1998). ([http://www.eia.doe.gov/cneaf/electricity/clean\\_air\\_upd97/exec\\_sum.html](http://www.eia.doe.gov/cneaf/electricity/clean_air_upd97/exec_sum.html))

### Energy Production and Consumption (Multifuel)

U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1997* (DOE, EIA, Washington, DC, 1998). (<http://www.eia.doe.gov/emeu/aer/contents.html>)

Davis, S.C., *Transportation Energy Databook* (DOE, Oak Ridge National Laboratory, Center for Transportation Analysis, annual). (<http://www.cta.ornl.gov/data/tedb.htm>)

### Energy Resources (Fossil and Nuclear)

U.S. Department of Energy, Energy Information Administration, *U.S. Coal Reserves 1997 Update* (DOE, EIA, Washington, DC, 1999). (<http://www.eia.doe.gov/cneaf/coal/reserves/front-1.html>)

—, *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1997 Annual Report* (DOE, EIA, Washington, DC, 1998). ([http://www.eia.doe.gov/oil\\_gas/natural\\_gas/data\\_publications/crude\\_oil\\_natural\\_gas\\_reserves/reserves\\_historical.html](http://www.eia.doe.gov/oil_gas/natural_gas/data_publications/crude_oil_natural_gas_reserves/reserves_historical.html))

See also *Uranium Industry Annual 1997* below.

### Natural Gas

U.S. Department of Energy, Energy Information Administration, *Natural Gas Annual 1997* (DOE, EIA, Washington, DC, 1998). ([http://www.eia.doe.gov/oil\\_gas/natural\\_gas/data\\_publications/natural\\_gas\\_annual/nga.html](http://www.eia.doe.gov/oil_gas/natural_gas/data_publications/natural_gas_annual/nga.html))

### Nuclear Energy

U.S. Department of Energy, Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report 1997* (DOE, EIA, Washington, DC, 1997). ([http://www.eia.doe.gov/cneaf/nuclear/n\\_pwr\\_fc/ng\\_sum.html](http://www.eia.doe.gov/cneaf/nuclear/n_pwr_fc/ng_sum.html))

—, *Uranium Industry Annual 1997* (DOE, EIA, Washington, DC, 1997). ([http://www.eia.doe.gov/cneaf/nuclear/uia/uia\\_sum.html](http://www.eia.doe.gov/cneaf/nuclear/uia/uia_sum.html))

U.S. Department of Energy, Office of Environmental Management, *Integrated Data Base Report—1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, Revision 13 (DOE, EM, Washington, DC, 1998) (<http://www.em.doe.gov/idb97/contents.html>)

### **Petroleum**

U.S. Department of Energy, Energy Information Administration, *Petroleum Supply Annual 1997* (DOE, EIA, Washington, DC, 1998). ([http://www.eia.doe.gov/oil\\_gas/petroleum/pet\\_frame.html](http://www.eia.doe.gov/oil_gas/petroleum/pet_frame.html))

### **Renewable Energy Resources**

U.S. Department of Energy, Energy Information Administration, *Alternatives to Traditional Transportation Fuels 1996* (DOE, EIA, Washington, DC, 1997). ([http://www.eia.doe.gov/cneaf/solar.renewables/alt\\_trans\\_fuel/attf\\_sum.html](http://www.eia.doe.gov/cneaf/solar.renewables/alt_trans_fuel/attf_sum.html))

—, *Renewable Energy Annual 1998 - (with data for 1997)* (DOE, EIA, Washington, DC, 1998). ([http://www.eia.doe.gov/cneaf/solar.renewables/rea\\_data/rea\\_sum.html](http://www.eia.doe.gov/cneaf/solar.renewables/rea_data/rea_sum.html))

## **RELATED ENERGY WEB SITES**

**Energy Information Administration** (<http://www.eia.doe.gov>) within the U.S. Department of Energy maintains web pages on a variety of energy-related subjects. Several are listed below.

**Alternative Fuels/Renewables Information at a Glance** - links to profiles, reports, and statistics on the following renewable energy resources and related subjects: biomass; municipal solid waste; geothermal; wind; solar; international renewable energy; environment; and electric industry restructuring. (<http://www.eia.doe.gov/fuelrenewable.html>)

**Coal Information at a Glance** - links to the following coal related subjects: industry overview; coke; consumption; distribution; employment; imports/exports; prices - end use; prices - mine production; productive capacity; productivity; quality; receipts; recoverable reserves; stocks. (<http://www.eia.doe.gov/fuelcoal.html>)

**Electric Information at a Glance** - links to data and reports on the following subjects: capability; capacity; consumers; demand side management; financial: investor-owned; fuel; generation; generating units; ownership; plants; revenue; and sales. (<http://www.eia.doe.gov/fuelectric.html>)

**Energy and Statistical Information on the Web** - links to national, state, local and international governments, associations, energy companies, and other energy information sources. (<http://www.eia.doe.gov/links.html>)

**Index to Energy Consumption Data** - links to reports and data on energy consumption by the following sectors: manufacturing; residential; households; residential transportation; and commercial. Also links to alternative fuels, measuring energy efficiency, and contacts. (<http://www.eia.doe.gov/emeu/consumption/>)

**Index to Environmental Publications and Data** - links to climate change and greenhouse gas emissions data, utility sector, transportation sector, environmental/energy legislation, and other environmental links See Chapter 11 for other websites on climate change and greenhouse gas emissions. (<http://www.eia.doe.gov/environment.html>)

**Index to Natural Gas Information Publications and Related Data** - links to annual, monthly, weekly, and other reports and related data; feature articles and special reports; and EIA's Specialized Natural Gas Information System (GIS). ([http://www.eia.doe.gov/oil\\_gas/natural\\_gas/nat\\_frame.html](http://www.eia.doe.gov/oil_gas/natural_gas/nat_frame.html))

**Index to Petroleum Information Publications and Related Data** - links to Annual, monthly, and weekly reports and related data; feature articles and special reports; presentations; survey forms and instructions; and PEDRO News. ([http://www.eia.doe.gov/oil\\_gas/petroleum/pet\\_frame.html](http://www.eia.doe.gov/oil_gas/petroleum/pet_frame.html))

**International Energy Themes** - links to data and reports on the following international energy subject areas: prices; country briefs; forecasts; chronologies; fact sheets; energy security; access database; privatization; restructuring; joint ventures; other finance; environment; data exchange; and reports. (<http://www.eia.doe.gov/emeu/international/contents.html>)

**Nuclear (and Uranium) Information at a Glance** - links to reports and data on U.S. nuclear reactors; forecasts; nuclear capacities; uranium requirements; enrichment requirements; spent fuel discharges; nuclear generating units. Also links to information on uranium resources: mining; production; processing; employment; marketing; enrichment; foreign purchases; foreign sales; and inventories. (<http://www.eia.doe.gov/fuelnuclear.html>)

**Alternative Fuels Data Center** - links to information on alternative fuels and vehicles operating on alternative fuels. (<http://www.afdc.nrel.gov/>)

## CORE DATA

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